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METHODS OF FORECASTING FUTURE ELECTRIC POWER REQUIREMENTS

by the Energy Division
United Nations Economic Commission for Europe

NOTE: This text is subject to editorial revision.

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I. Introduction

In many parts of the world, and certainly in the countries of Europe, growth-rates for electric power consumption have in recent years been almost uniformly high. Consumption has generally been growing far more rapidly and evenly than the steadily-rising output of goods and services and its domestic use has risen faster than the number of household consumers. As an outcome of these trends, more and more of the total primary energy required by the various national economies is tending to be consumed in the form of electricity. A long-term process of net replacement or substitution is thus at work in most countries, though at rates varying according to the pattern of energy supply and natural resources. Forecasts of electric power requirements, expressed in terms of consumption or of growth in load, are commonly either medium-term (looking 5-10 years ahead) or long-term in character. Short-term plans or forecasts are also employed, largely for operational and maintenance programmes.

In Europe, the different countries vary widely in their degree of industrialization; in the possession of diversified natural energy resources; in mode of economic organization; and in their stage of electrification as represented by average consumption per head. Characteristic rates of consumption growth vary correspondingly. The ever-present need for careful investment to extend power supply systems has led under the different national conditions to a use of diversified forecasting techniques. To make knowledge of the different methods as widely available as possible, the Committee on Electric Power of ECE has investigated the procedures employed through an ad hoc Group of Experts. The results of this inquiry have been published.[1/] Attention has also been given to consumption tendencies and their assessment in a

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1/ Methods Employed for the Determination of Electric Power Consumption Forecasts (E/ECE/224).

/review of

review of basic developments in the supply situation in Europe over the post-war period[2] as well as in recent annual surveys on the development of the electric power supply industry in Europe[3] prepared by the Secretariat.

The report which follows is in two main parts. The first outlines some salient aspects of the main forecasting techniques employed under European conditions and the second sums up certain basic considerations on forecasting as derived from a study of trends in that region. The above-mentioned documents, and certain bibliographical references given later, will be found to provide additional details on the matters discussed.

2. Types of forecasting method

(a) Treatment of statistical data

All types of plan or forecast are based ultimately on a body of data obtained by studying past developments. To use such statistical series it is in general necessary to remove effects due to many extraneous influences - economic or seasonal influences due to strikes and holiday periods, for example, or climatic factors due to fluctuations in temperature and light conditions or to hydraulic conditions affecting production and thereby also certain types of consumption.

One method of reducing dispersion between different rates of change at different times and in different countries is that of assembling a series of long-term trends plotted from consecutive years and plotting them all together from the same point as origin. The resulting "bunch" of trends can then be summarized by plotting the median curve

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2/ Developments in the Situation of Europe's Electric Power Supply Industry During the Post-War Period (E/ECE/367), chapter I.

3/ See The Electric Power Situation in Europe in 1957 (E/ECE/359); The Electric Power Situation in Europe in 1958/59 and its Future Prospects (ST/ECE/EP/2), chapter II; The Situation and Prospects of the Electric Power Supply Industry in Europe in 1959/60 (ST/ECE/EP/9), chapters I and II.

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and the upper and lower quartiles, and thus can be used as a starting point for estimating by simple extrapolation.4/

The method of deriving a "corridor" or "reliability interval" from past statistical trends is also used, particularly where seasonal series are included. Here the purpose is to determine upper and lower limits within which the effective values of subsequent empirical series can reasonably be expected to be included.

In some European countries simple averages for mean consumption per month or per working day in each month are worked out, effective consumption being divided by the number of working days. For this purpose Saturdays, Sundays and public holidays may be allowed for by a use of suitable factors.

The use of moving averages to reduce short-term fluctuations has the drawback of introducing a certain time-lag. For this reason the use both of a corrected monthly consumption and of its corresponding moving average has been advocated by UNIPEDE, which publishes for certain countries both normal monthly trends in consumption and corrected trends which eliminate both the regular seasonal fluctuation and the effect of holidays. As used by UNIPEDE, coefficients for seasonal variation are obtained by dividing monthly consumption (corrected for working days) by the corresponding value of the moving average. A corrected consumption is then given by dividing each monthly consumption figure by its corresponding average seasonal variation coefficient. The trend so obtained reflects more clearly the effect of variations in economic activity on the development of electricity consumption.

The influence on daily load of departures from average temperature and light conditions is allowed for in some European countries which depend more particularly on thermal power. So far as annual consumption is concerned, the effect of fluctuating weather conditions in winter

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4/ The method is discussed in the Circulaire Périodique N°19 of the International Union of Producers and Distributors of Electric Power (UNIPEDE) Paris, 1952.

quarters is of special importance in a few of these. This last question has been examined comprehensively for the first time, so far as European countries are concerned, in document ST/ECE/EP/9. To assess the influence on a series of consecutive consumption data (C) of a departure from long-term average temperature of 1°C (T) it is necessary to separate this factor from that due to changes in economic activity. If the latter is reflected for example by a percentage rate of change in the manufacturing production index (M), the average influence of T can (in principle) be deduced approximately by calculating a partial regression equation of the general form $C = aM + b T + c$. Within the limits of the data, this allows the percentage changes in C corresponding to a 1° departure from average T or a one per cent change in M to be expressed separately, the other in each case being assumed to be held constant.

(b) Classification of methods employed

After taking the foregoing conditions into account, the principal methods of forecasting employed in Europe may be divided into two main categories:

- those founded on the application of a mean rate (or rates) of annual change;
- those concerned with summing the separate requirements of the various consumption sectors.

(i) Methods based on determining a mean rate of change

Variations of this type of method are very commonly used in Europe. The assumptions employed may be such as to lead to a constant exponential rate of change applicable to a limited period; to a gradually regressive rate; or to rates of change based on the evolution of the various factors governing consumption, as derived from fairly complex empirical formulae.

The well-known constant rate based on a doubling of consumption in each decade (equivalent to 7.2 per cent per year) is broadly characteristic of conditions in Western Europe at present. Average rates of increase of a similar order are implied by forecasts prepared for a number of

/countries over

countries over the next five years (see document ST/ECE/EP/9). Lower long-term rates are found to characterize certain countries; for example around 4 per cent for Switzerland. Such constant average rates can however give only broad general indications.

In line with the fact that exponential rates of growth cannot persist indefinitely, certain countries consider that the future development of their electricity consumption should be regressive in character, conforming broadly to the model of a logistic trend which on normal arithmetic scales gives an S-shaped curve.5/ This type of development is for example adopted as a basis in Austria. Use of the theoretical S-curve as a model raises the difficulty that the essential parameter - the point of inflexion defining the change to declining rates of growth - has not in general been accurately determined for any particular country. For the United Kingdom a simple formula checked by figures over the last fifty years gives a regressive percentage rate of increase derived from the expression.

$$\frac{492}{t - 1878}$$

where t is the year for which the rate is required and 1878 the starting point for United Kingdom consumption statistics.6/ A similar type of formula for tendencies in world consumption has also been worked out.

From an analysis of future growth rates implied in the latest forecasts and plans prepared by many European countries up to 1975, it can be seen that a certain number of those which are more highly electrified are in fact postulating gradually decelerating rates for the future. This however does not necessarily arise purely from the use of regressive formulae, since it is possible to increase successive long-term forecasts gradually, as later experience may dictate. The

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5/ The generalized expression for a logistic trend is:

$$\log E = \frac{C}{1 + me^{-at}}$$

where E (in the present case) represents electricity consumption; C is the upper asymptote corresponding to "saturation"; a and m are constants; and t represents time.

6/ The formula derives from: $E = 58.8 \left(\frac{t - 1878}{74}\right)^{4.92} \times 10^9$ kWh.

See G.H. Daniel "The energy requirements of the United Kingdom", United Nations, Proceedings of the International Conference on the Peaceful Uses of Atomic Energy, Volume 1.

/appropriate data

appropriate data will be found in document ST/ECE/EP/9 referred to above (particularly Chapter II) where an example of a regressive forecast for Austria is also set out in detail.

Such considerations have led M. P. Ailleret to suggest an expression in which consumption is assumed to increase as the product of two factors, the one proportionate to the trend of output (i.e. P^n, P being the index of industrial production and n lying between 0.33 and 0.50); and the other a trend factor reflecting the process of electrification in time and increasing exponentially at a rate equivalent to doubling in 13-14 years.7/ Other expressions of a somewhat similar nature have been derived for medium and short-term forecasting covering consumption for industrial purposes. Thus the exponential functions of the above formula have in one case been replaced by linear functions and in the second case by a new term covering use of manpower.8/

In some countries, such as Italy, government authorities have employed rates of increase in population and consumption per inhabitant as a basis for their forecasts. Although many different economic correlates of electric power consumption can be distinguished, most formulae of the type under discussion are based on the index of industrial output. An example applied to conditions in Belgium uses the expression:

$$E = k : M^{0.6} \times 2^{0.465\,t}$$

where E = electricity consumption

M = index of manufacturing production

t = time, and

k = an adjustment factor.

(ii) Methods based on assessing total requirements of different consumer-groups

Methods of this general type comprise three categories. Some examples of these for different European countries are outlined in

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7/ See UNIPEDE, Circulaire Périodique N° 18,

8/ See UNIPEDE, Economie électrique N°4 (relating to a study by the Union pour l'étude du marché de l'électricité).

Part II of document E/ECE/224 referred to earlier. In the first place many countries carry out surveys at intervals, based in part on questionnaires, to evaluate future requirements in the main consumption sectors such as those of industry. Surveys of this kind may be broken down to a series of regional investigations which make use of special local experience. By summing the results of the separate estimates for different consumer-groups, a detailed forecast is obtained which is normally checked by comparison with overall forecasts made in other ways.

A related procedure which has been employed in a few countries, including Italy, is to apply the method of the Leontief input-output matrix. Such a matrix shows the interrelations of purchases and sales in all the various economic sectors and from it percentage increases in electricity requirements have sometimes been worked out in conformity with the implications of growth estimates for the economy as a whole.9/

The third type of sector analysis is that made in preparing overall economic plans for countries possessing a centrally directed or planned economy. On the basis of assessed production plans for different sectors of industry, and for various agricultural, transport and domestic needs, electric power balances are worked out from specific data on kWh required per unit of product, per ton/km, per hectare of arable land, and so on. These norms take account of various modifying influences, including those due to technical progress and progressive economies in consumption. Planned requirements based on demand coefficients for the various types of consumers in different districts are also worked out.

3. Considerations bearing on assessment of consumption requirements

In practice two or more of the foregoing methods are usually applied concurrently in order to give a check on the results. The procedure employed will also depend in some degree on the mode of organization

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9/ In a somewhat analogous econometric approach to overall economic forecasting, a number of attempts have recently been made to forecast the short-term development of a total national economy by constructing "models" based on the interrelations of a selection of measurable economic variables.

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both of the national economy and of the power supply industry, as well as on the length of the period to which the forecast applies. Another factor, which tends to influence the assessment in differing degree in different countries, is the limiting-role of production possibilities. In some countries that are less-electrified and incompletely interconnected the limits to these may largely determine the rate at which consumption develops. Moreover in countries relying particularly on hydro-power, where certain special types of consumer are attracted by their large low-cost off-peak requirements for electric power, the structure of industry is likely to be different from that in countries possessing a different pattern of natural resources. The size of the industrial consumption sector relative to the total may also be a factor when choosing to apply separate sector analyses because of the greater difficulty in studying the requirements of household and other low-voltage consumers.

Finally, forecasts of electric power requirements should be closely concerned with the role of electric energy relative to total use of different forms of primary energy so as to be able to take into account prospects of replacement or substitution. A number of European countries, including Austria, Belgium, Italy, and Switzerland, have undertaken the preparation of detailed energy balances; and such investigations offer a useful corrective to estimates of electric power requirements arrived at in other ways.

Europe comprises many distinct types of national economy, and these enjoy widely different levels of electrification and possess varied patterns of natural resources. Studied collectively, their various long-term tendencies in use of electric power offer some indications as to characteristics of consumption trends at different stages of the electrification process and at different stages of economic growth. Such investigations are particularly fruitful in comparing the evolution of consumption relative to gross national product, industrial output, employment in industry, housing construction, total use of primary commercial energy and other related indices.

/Comparative study

Comparative study on these lines affords some useful guidance. In the short term, relationships between consumption and its main economic correlates change far more slowly and consistently than do the individual categories themselves. Moreover, these relationships are essentially similar in character in planned and unplanned economies alike. For the longer term, comparison of the development of such relationships in countries at widely different stages of electrification - for example, with respect to rates of increase, consumption per unit of national product, replacement by electricity in total energy supply, etc. - is found to throw light on the likely long-term evolution of electric power requirements.

In all European countries the evolving position in those countries with high specific consumption, such as Norway and Sweden, is inevitably a useful index, and in some cases fuller comparative studies are already used to assist forecasting. The ECE Secretariat has of late explored some aspects of this subject in relation to European conditions. Fuller details will be found in certain of the studies referred to earlier.[10/]

4. Bibliography

In addition to the references in the text to relevant ECE documents, the following sources are among those of interest in relation to the subjects discussed:

1. H.J. Beard A.W. Pedder: forecasting Electricity Requirements; World Power Conference, (Paper N° IB/7), Madrid, 1960.
2. H. Steiner: Energieprognosen in Theorie and Praxis; Elektrizitätswirtschaft, Frankfurt/Main, N°17, September 1959.
3. F. Petri: Forecasts of Power Consumption; Skandinaviska Banken, Quarterly Review, Vol. XXV, N°3, Stockholm, 1954.

10/ Documents E/ECE/359 (Chapter I); ST/ECE/EP/2 (Chapter 2); ST/ECE/EP/9 (Chapter II); and E/ECE/367 (Chapter I).